Designation: C1651 – 11 (Reapproved 2018)

Standard Test Method for Measurement of Roll Wave Optical Distortion in Heat-Treated Flat Glass[1]

This standard is issued under the fixed designation C1651; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method is applicable to the determination of the peak-to-valley depth and peak-to-peak distances of the out-of-plane deformation referred to as roll wave which occurs in flat, heat-treated architectural glass substrates processed in a heat processing continuous or oscillating conveyance oven.

1.2 This test method does not address other flatness issues like edge kink, ream, pocket distortion, bow, or other distortions outside of roll wave as defined in this test method.

1.3 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 Reference to these documents shall be the latest issue unless otherwise specified by the authority applying this test method.

2.2 *ASTM Standards:*[2]

C162 Terminology of Glass and Glass Products

C1036 Specification for Flat Glass

C1048 Specification for Heat-Strengthened and Fully Tempered Flat Glass

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *peak-to-valley depth of roll wave*—characteristic depth, *W*, of roll wave as illustrated in Fig. 1.

3.1.2 *peak-to-peak wavelength of roll wave*—characteristic length, *L*, of roll wave shown as a sine-wave representing the deformed surface section as illustrated in Fig. 1.

3.1.3 *roll wave*—A repetitive wave-like departure from flatness in glass that results from heat treating the glass in a horizontal roller hearth furnace. Roll wave excludes edge effects such as edge kink and distortion influenced by assembly or installation.

3.1.4 *roll wave optical distortion*—visual distortion, *D*, that results from roll wave and expressed as lens power as in Eq 1.

3.1.5 *valley-to-valley wavelength of roll wave*—characteristic length, *L*, of roll wave shown as a sine-wave representing the deformed surface section as illustrated in Fig. 1.

4. Summary of Test Method

4.1 This test consists of moving an instrument across the glass surface in a direction parallel to the direction that the glass substrate traveled during heat processing. The instrument will primarily measure the out-of-plane deformation of the glass surface which is characteristic of the glass and known as "roll wave". The peak-to-valley depths of the roll waves, *W*, and the peak-to-peak distances, *L*, are measured. (See Fig. 1.)

4.1.1 Other out-of-plane deformations of the glass surface may also be present which do not have the same peak and valley wave character of the roll wave, but which also result in the appearance of optical distortion in the glass.

4.1.2 The optical distortion due to the out-of-plane deformation of the surface is measured as an optical power, similar to the optical power of a cylindrical mirror or lens.

4.1.3 For those deformations that do have a wave character, the distortion can be calculated using the following formula. From the measured roll wave depth, *W* and the measured

[1] This test method is under the jurisdiction of ASTM Committee C14 on Glass and Glass Products and is the direct responsibility of Subcommittee C14.11 on Optical Properties.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

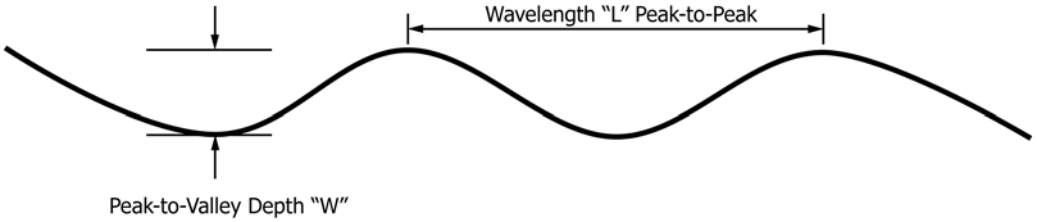

FIG. 1 Representative Roll Wave Showing *"W"* and *"L"*

peak-to-peak or valley to valley wavelength of the roll wave, L, the optical roll wave distortion D is:

$$D = 4\pi^2 W/L^2 \quad (1)$$

where W and L are in metres and D is in diopters. The dimensions of diopters (dpt) is m^{-1}. The more usual unit of optical distortion is millidiopters which are obtained by multiplying the value in diopters by 1000.

4.2 Appendix X1 and references show the relationship between W, L, the measured radius of curvature R and the optical distortion of a reflecting surface, D.

5. Significance and Use

5.1 This test method is a procedure for determining the peak-to-valley depth and the wavelength of roll wave in flat glass and then calculating the optical distortion resulting from that roll wave. Peak-to-valley measurements provide a means of monitoring the roll wave distortion in a heat processed glass product.

5.2 Measured peak-to-valley depth provides information required by some specifiers of heat-treated glass products.

5.3 Roll wave is inherent in flat glass which has been heat treated in a furnace in which rollers are used to convey the glass.

5.4 Consult Specifications C1036 and C1048 for additional glass characteristics and quality information.

6. Apparatus

6.1 Optical distortion in flat glass can be characterized by determining the out-of-plane deformation of the glass by use of an instrument to measure the peak-to-valley depth of the deformations. Two such instruments are the so-called "Flat Bottom" Gauge and the "Three Point Contact" Gauge. (As stated in 10.1 a Round Robin Interlaboratory Study (ILS) will be carried out to establish, among other things, the comparative precision and bias of measurement made with the "Flat Bottom" Gauge and the "Three Point Contact" Gauge.)

6.2 The "Flat Bottom" Gauge consists of a flat plate which is a minimum of 12 in. (305 mm) long. (The flat plate shall be equal to or greater in length than the circumference of the furnace roller and less than twice the circumference of the roller.) It shall be no less than 2 in. (50.8 mm) wide, with a smooth, low-coefficient of friction surface and have a depth measuring gauge equipped with a dial indicator, digital micrometre, or linear variable differential transformer (LVDT) with a protruding ball-end spring loaded plunger. This indicator, micrometre, or LVDT is used to measure the out-of-plane depth, W, of valleys and is located at the center of the bar. Such a gauge is shown in Fig. 2.

6.3 The "Three Point Contact" Gauge has three contact points, one at each end of the gauge and equally spaced from a center contact point at which position the depth of the roll wave is measured. The distance between the outboard contact

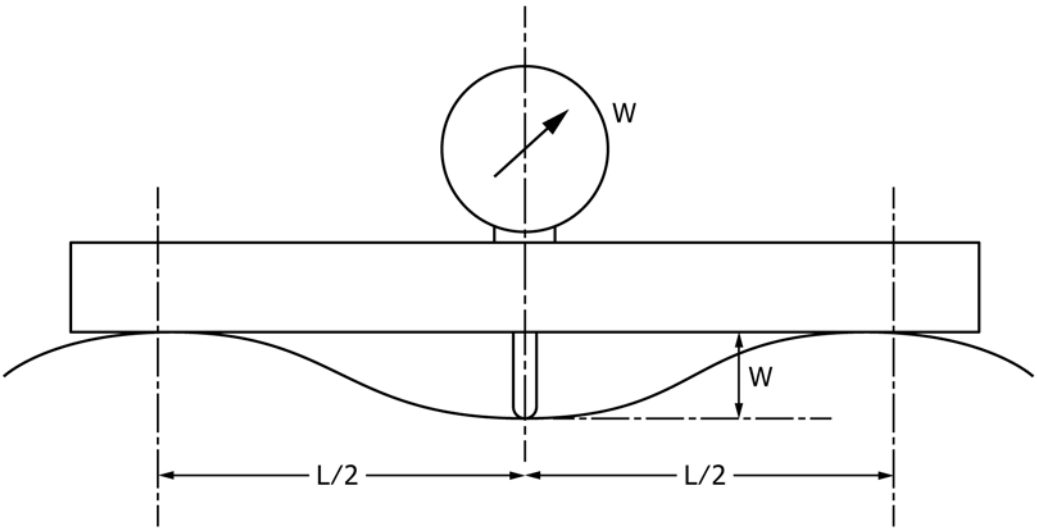

FIG. 2 "Flat Bottom" Roll Wave Gauge with Dial Indicator